

In re Patent Application of:  
**PORTO ET AL.**  
Serial No. 10/701,150  
Filing Date: **NOVEMBER 4, 2003**

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**In the Claims:**

Claims 1-6 (Cancelled).

7. (Proposed Claim Amendment) A processing device for implementing a quantum gate for running a quantum algorithm for searching elements in a database using a binary function having a first basis of vectors of  $n$  qubits, the processing device quantum gate comprising:

a superposition subsystem for performing a superposition operation over components of input vectors for generating components of linear superposition vectors for a second basis of vectors of  $n+1$  qubits;

an entanglement subsystem for performing an entanglement operation over components of the linear superposition vectors for generating components of entanglement vectors, said entanglement subsystem comprising

a command circuit for generating a plurality of logic command signals encoding values of the binary function corresponding to the first basis of vectors, and

an array of multiplexers, each being driven by a respective logic command signal and receiving as input a plurality of signals representing components of a linear superposition vector corresponding to the second basis of vectors having the first  $n$  qubits in common, and outputting for each superposition vector corresponding signals representing components of an entanglement vector, each component of the entanglement

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vector corresponding to a respective vector of the second basis of vectors and being equal to

the corresponding component of the respective superposition vector if the binary function is null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors, or

the opposite of the corresponding component of the respective superposition vector if the binary function is not a null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors; and

an interference subsystem for performing an interference operation over components of the entanglement vectors for generating components of output vectors representing the elements searched in the database.

8. (Previously Presented) A quantum gate according to Claim 7, wherein the quantum algorithm comprises a Grover's quantum algorithm, and wherein said interference subsystem comprises:

an adder receiving as input voltage signals representing even or odd components of an entanglement vector, and generating a sum signal representing a weighed sum with a scale factor of the even or odd components of the entanglement vector; and

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an array of adders each receiving as input a respective signal representing an even or odd component of an entanglement vector and the sum signal, and generating a signal representing an even or odd component of the output vector as a difference between the sum signal and the signal representing an even or odd component of the entanglement vector.

9. (Previously Presented) A quantum gate According to Claim 7, wherein the quantum algorithm comprises a Deutsch-Jozsa's quantum algorithm, and wherein said interference subsystem comprises an array of adders each receiving as input signals representing even or odd components of an entanglement vector, and generating a signal representing a corresponding even or odd component of the output vector as a linear combination of the signals representing the even or odd components of the entanglement vector.

10. (Previously Presented) A quantum gate according to Claim 8, further comprising an elaboration subsystem comprising:

an analog/digital converter receiving as input the signals representing the even or odd components of the output vector and for converting the input signals into a digital string; and

a microprocessor unit receiving as input the digital string for performing the following

calculating a quantity to be minimized that is associated with the odd or even components of the output vector,

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comparing the quantity to be minimized with a threshold and stopping the Grover's algorithm if the quantity is smaller than the threshold, otherwise commanding another iteration, and

generating an output digital string representing components of the output vector.

11. (Previously Presented) A quantum gate according to Claim 10, wherein said elaboration subsystem further comprises:

a digital/analog converter receiving as input the output digital string, and generating output signals corresponding to the odd or even components of the output vector; and

an array of level shifters, each being input with a respective output signal, and generating a pair of voltage signals in a desired voltage range representing opposite components of a new superposition vector to be input to said entanglement subsystem.

12. (Previously Presented) A quantum gate according to Claim 11, wherein each level shifter comprises:

an adder that subtracts a predetermined voltage from a respective output signal for generating an odd component of the new superposition vector; and

an inverter receiving as input the odd component for generating the corresponding even component.

Claim 13 (Cancelled).

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14. (Previously Presented) A quantum gate according to Claim 10, wherein the quantity to be minimized comprises a Shannon entropy.

15. (Proposed Claim Amendment) A processing device for implementing a quantum gate for running a Grover's quantum algorithm for searching elements in a database using a binary function having a first basis of vectors of  $n$  qubits, the processing device ~~quantum gate~~ comprising:

a superposition subsystem for performing a superposition operation over components of input vectors for generating components of linear superposition vectors for a second basis of vectors of  $n+1$  qubits;

an entanglement subsystem for performing an entanglement operation over components of the linear superposition vectors for generating components of entanglement vectors, said entanglement subsystem comprising

a command circuit for generating a plurality of logic command signals encoding values of the binary function corresponding to the first basis of vectors, and

an array of multiplexers, each being driven by a respective logic command signal and receiving as input a plurality of signals representing components of a linear superposition vector corresponding to the second basis of vectors having the first  $n$  qubits in common, and outputting for each superposition vector

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corresponding signals representing components of an entanglement vector; and  
an interference subsystem for performing an interference operation over components of the entanglement vectors for generating components of output vectors representing the elements searched in the database.

16. (Previously Presented) A quantum gate according to Claim 15, wherein each component of the entanglement vector corresponding to a respective vector of the second basis of vectors is equal to the corresponding component of the respective superposition vector if the binary function is null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors, or the opposite of the corresponding component of the respective superposition vector if the binary function is not a null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors.

17. (Previously Presented) A quantum gate according to Claim 15, wherein said interference subsystem comprises:

an adder receiving as input voltage signals representing even or odd components of an entanglement vector, and generating a sum signal representing a weighed sum with a scale factor of the even or odd components of the entanglement vector; and

an array of adders each receiving as input a respective

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signal representing an even or odd component of an entanglement vector and the sum signal, and generating a signal representing an even or odd component of the output vector as a difference between the sum signal and the signal representing an even or odd component of the entanglement vector.

18. (Previously Presented) A quantum gate according to Claim 17, further comprising an elaboration subsystem comprising:  
an analog/digital converter receiving as input the signals representing the even or odd components of the output vector and for converting the input signals into a digital string; and

a microprocessor unit receiving as input the digital string for performing the following

calculating a quantity to be minimized that is associated with the odd or even components of the output vector,

comparing the quantity to be minimized with a threshold and stopping the Grover's algorithm if the quantity is smaller than the threshold, otherwise commanding another iteration, and

generating an output digital string representing components of the output vector.

19. (Previously Presented) A quantum gate according to Claim 18, wherein said elaboration subsystem further comprises:

a digital/analog converter receiving as input the output digital string, and generating output signals

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corresponding to the odd or even components of the output vector;  
and

an array of level shifters, each being input with a respective output signal, and generating a pair of voltage signals in a desired voltage range representing opposite components of a new superposition vector to be input to said entanglement subsystem.

20. (Previously Presented) A quantum gate according to Claim 19, wherein each level shifter comprises:

an adder that subtracts a predetermined voltage from a respective output signal for generating an odd component of the new superposition vector; and

an inverter receiving as input the odd component for generating the corresponding even component.

21. (Previously Presented) A quantum gate according to Claim 18, wherein the quantity to be minimized comprises a Shannon entropy.

22. (Proposed Claim Amendment) A processing device for implementing a quantum gate for running a Deutsch-Jozsa's quantum algorithm for searching elements in a database using a binary function having a first basis of vectors of  $n$  qubits, the processing device ~~quantum gate~~ comprising:

a superposition subsystem for performing a superposition operation over components of input vectors for generating components of linear superposition vectors for a



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second basis of vectors of  $n+1$  qubits;

an entanglement subsystem for performing an entanglement operation over components of the linear superposition vectors for generating components of entanglement vectors, said entanglement subsystem comprising

a command circuit for generating a plurality of logic command signals encoding values of the binary function corresponding to the first basis of vectors, and

an array of multiplexers, each being driven by a respective logic command signal and receiving as input a plurality of signals representing components of a linear superposition vector corresponding to the second basis of vectors having the first  $n$  qubits in common, and outputting for each superposition vector corresponding signals representing components of an entanglement vector; and

an interference subsystem for performing an interference operation over components of the entanglement vectors for generating components of output vectors representing the elements searched in the database.

23. (Previously Presented) A quantum gate according to Claim 22, wherein each component of the entanglement vector corresponding to a respective vector of the second basis of vectors is equal to the corresponding component of the respective superposition vector if the binary function is null in correspondence to the vector of the first basis of vectors formed

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by the first  $n$  qubits of the respective vector of the second basis of vectors, or the opposite of the corresponding component of the respective superposition vector if the binary function is not a null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors.

24. (Proposed Claim Amendment) A method for operating a processing device comprising a superposition subsystem, an entanglement subsystem and an interference subsystem for running a quantum algorithm for searching elements in a database ~~or for a decision-making process~~ using a binary function having a first basis of vectors of  $n$  qubits, the method comprising:

performing a superposition operation with the superposition subsystem over components of input vectors for generating components of linear superposition vectors for a second basis of vectors of  $n+1$  qubits;

performing an entanglement operation with the entanglement subsystem over components of the linear superposition vectors for generating components of entanglement vectors, the entanglement operation comprising

generating a plurality of logic command signals encoding values of the binary function corresponding to the first basis of vectors, and

driving an array of multiplexers by respective logic command signals and applying as input to the array of multiplexers a plurality of signals representing components of a linear superposition

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vector corresponding to the second basis of vectors having the first  $n$  qubits in common, and outputting for each superposition vector corresponding signals representing components of an entanglement vector, each component of the entanglement vector corresponding to a respective vector of the second basis of vectors and being equal to

the corresponding component of the respective superposition vector if the binary function is null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors, or

the opposite of the corresponding component of the respective superposition vector if the binary function is not a null in correspondence to the vector of the first basis of vectors formed by the first  $n$  qubits of the respective vector of the second basis of vectors; and

performing an interference operation with the interference subsystem over components of the entanglement vectors for generating components of output vectors corresponding to ~~an item being~~ the elements searched in the database ~~or a result of the decision making process.~~

25. (Proposed Claim Amendment) A method according to Claim 24, wherein the quantum algorithm comprises a Grover's quantum algorithm; and wherein the ~~interference operation is~~

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~~performed using an~~ interference subsystem comprises ~~comprising~~  
an adder receiving as input voltage signals  
representing even or odd components of an entanglement vector,  
and generating a sum signal representing a weighed sum with a  
scale factor of the even or odd components of the entanglement  
vector; and

an array of adders each receiving as input a respective  
signal representing an even or odd component of an entanglement  
vector and the sum signal, and generating a signal representing  
an even or odd component of the output vector as a difference  
between the sum signal and the signal representing an even or odd  
component of the entanglement vector.

26. (Proposed Claim Amendment) A method according to  
Claim 24, wherein the quantum algorithm comprises a Deutsch-  
Jozsa's quantum algorithm; and wherein the ~~interference operation~~  
~~is performed using an~~ interference subsystem comprises ~~comprising~~  
an array of adders each receiving as input signals representing  
even or odd components of an entanglement vector, and generating  
a signal representing a corresponding even or odd component of  
the output vector as a linear combination of the signals  
representing the even or odd components of the entanglement  
vector.

27. (Previously Presented) A method according to Claim  
25, further comprising:

receiving as input the signals representing the even or  
odd components of the output vector, and converting the input

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signals into a digital string; and  
performing the following based upon the digital string  
calculating a quantity to be minimized that is  
associated with the odd or even components of the  
output vector,  
comparing the quantity to be minimized with a  
threshold and stopping the Grover's algorithm if the  
quantity is smaller than the threshold, otherwise  
commanding another iteration, and  
generating an output digital string representing  
components of the output vector.

28. (Previously Presented) A method according to Claim 27, further comprising:

generating output signals corresponding to the odd or even components of the output vector; and  
using an array of level shifters, each being input with a respective output signal, and generating a pair of voltage signals in a desired voltage range representing opposite components of a new superposition vector to be input to an entanglement subsystem performing the entanglement operations.

29. (Previously Presented) A method according to Claim 28, wherein each level shifter comprises:

an adder that subtracts a predetermined voltage from a respective output signal for generating an odd component of the new superposition vector; and

an inverter receiving as input the odd component for

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generating the corresponding even component.

30. (Previously Presented) A method according to Claim 27, wherein the quantity to be minimized comprises a Shannon entropy.